Names____
Section ________

PHYSICS 315 –AVIATION PHYSICS

Application Exercise 1

Fight the Vertical Fight!

Due: *Beginning of class*, lesson 9

100 points

To receive full credit you must show all work and communicate efficiently using proper grammar.

AUTHORIZED RESOURCES: *any published or unpublished sources and any individuals*.

Document appropriately!

PART ONE

This application exercise is designed to tie together all of the concepts we've been discussing in the first part of the course. Energy, maneuverability, turn rate and radius, radial acceleration--all of these things play into the crucial split-second choices one must make to win or lose the air-to-air fight.

In this application lesson, you will use an iterative numerical technique (the Euler method) to see how initial airspeed and G-loading affect the relevant parameters of a turning F-4. Given a very rough P_s calculation method, you will determine appropriate formulae for the time changes in airspeed, turn rate, turn radius and tangential acceleration for the Mighty Rhino. You will also quickly discover that you will have to modify the Gs you are pulling if you are to continue turning without encountering a <u>stall</u>. The choices you make will automatically be transformed into graphical output that show the changes in the F-4's parameters.

<u>PART ONE INSTRUCTIONS AND QUESTIONS</u>

Loaded onto the classroom computers you will find a file called Level Turn.xls. Open this file with Microsoft Excel. **DO NOT MODIFY THIS FILE. SAVE IT TO YOUR PERSONAL DISK BEFORE PROCEEDING.** You will see that the file is a workbook containing one data entry sheet and several graph sheets. Open the data entry sheet. The very top portion of the sheet is my best hack at putting the P_s vs. altitude (only at 10000ft) and airspeed chart from Bretana into numerical form. To use it, simply input an airspeed you're interested in into the green box and –voila—out pops the P_s for 1 to 6 Gs at 10000ft. This is just a gee-whiz exercise, and will just let you get a feel for what changing airspeed does to P_s at different load factors. **DO NOT CHANGE THE FORMULAE IN THIS SECTION OR THE REST OF YOUR APPLICATION LESSON WILL FAIL MISERABLY!** You should only change the number in the green box.

Below the lower black bar is the meat of the lesson. You should find a row with column headings including things such as airspeed, Mach number, etc. Below this row is another row with the appropriate units. These units are important! I'd be willing to bet that a vast majority of your errors in this lesson will come from insufficient dimensional analysis – certainly, most of my errors when I was writing the key came from this source! (There is method to my madness--this is just another example of how archaic the English system of units is compared to the SI system. You'll soon learn to hate them as much as I do).

The first line below the gray bar is where you will enter a few formulae and a few initial conditions. Some initial conditions are given: initial airspeed (450 kts), initial altitude (10,000 ft), initial location on the turn circle (0 degrees), initial load factor (6 Gs), and initial time (0 seconds). There are also several formulae I've provided for you, notably, the specific energy formula that depends upon altitude and airspeed, and the airspeed-dependent Mach number formula. Also note that the blue and yellow boxes contain formulae for calculating $P_{s.}$ This will become important when you decide (or are forced) to change the number of Gs you are pulling. **Do not change any of the given formulae!**

The next row contains blocks that deal with the same parameters, but one time-step later (this is the key to a successful Euler Method computation). Example formulae are provided in the time, load factor, Mach number, and average turn rate columns.

Your main task for this first portion of the exercise is to decide what formulae go in the red blocks in the first two rows of the spreadsheet. The rate/radius/acceleration formulae come directly from the equations derived in previous lectures.

What's really going on in this exercise? You and Excel are applying Euler's Method to model the turn capabilities of an F-4. The P_s values are based on full afterburner: your left hand has pushed the throttles full forward…the jet's giving all it's got! As with a real max-performance level turn, the only thing you can change is your bank angle, and therefore the number of G's you are pulling.

1. **Write down in standard mathematical symbols the equations you want to put in the red blocks . These neatly handwritten equations must be turned in with your final report.**

I don't expect you to be Excel formula wizards (yet), so take a shot at turning your formulae into something the spreadsheet will understand, and then ask me for help. If I'm not around, get help from anyone who knows Excel to translate your equations into Excel-speak. As always, DOCUMENT this help. Once you have the acceleration formula complete, you can take this formula, multiply it by the time step, and use it in the second line's formula for velocity to find out what the new velocity will be. Use this new velocity in the cells that calculate the rest of the second row's data. Once all the cells in the second row are filled with appropriate formulae, **copy the SECOND row** down for 200 rows. Eventually something strange will happen to your aircraft.

2. **Tell me what this strange occurrence is, and why it happened. Fix the problem by changing the way you're flying the jet. Tell me how you solved the problem (you are NOT allowed to alter the P_s formulae)!**

Continue "flying" your Rhino (copying rows and fixing any problems that occur) until you've completed a 180 degree turn.

I will award **25 bonus points** to any lab group who can fly their F-4 through a level 180 degree turn in equal or better time than my best effort. I will award **an additional 25 bonus points** to the lab group in each section who can make the turn in the shortest time of all your peers. It's not fair to change the P_s formulae (after all, a Rhino is a Rhino), but you may change the ***initial*** airspeed going into the turn, and feel free to adjust the load factor throughout the turn.

NOTE: LOAD FACTOR MAY ONLY BE ENTERED IN THE SPREADSHEET AS AN INTEGER. FOR EXAMPLE, 5 IS A VALID LOAD FACTOR, WHILE 5.3 IS NOT!

3. **Briefly describe your strategy for minimizing the time it takes to turn the jet 180 degrees. Tell me what you did and why.**

4. **Briefly describe each of the graphs generated from your data. I only want a short paragraph for each graph, explaining WHY the graphs look the way they do. Things to include are explanations of "why does this one increase?", "why does that one decrease?", "why is there a discontinuity here?", "why is there a local maximum/minimum here?", etc. <u>This list is not all-inclusive</u>, so try to tell me the points you think are the most relevant. Let me know what you've learned from this exercise and its output. Make sure you include a copy of each of your graphs, and clearly indicate your best time-to-turn.**

PART TWO

Now we will look at a purely vertical turn. On your computers you will find an Excel program called Vertical Turn.xls: open it!

<u>PART TWO INSTRUCTIONS AND QUESTIONS</u>

You have several tasks for this remaining portion of the exercise. First, I'd like you to take a look at the new columns in this spreadsheet (I've colored them orange). **<u>Do not change any of the given formulae!</u>**

1. **Tell me why these new columns are required for the vertical turn and not for the level turn.**

2. **What are the formulae the new columns contain? (write these down <u>neatly</u> in standard mathematical notation and give a brief explanation of what each does)**

3. **Does this spreadsheet model an initial pull-up (bottom of a loop) or an initial pull-down (top of a loop)? How would you change the formulae to turn the pull-up into a pull-down, or vice-versa?**

4. **List any simplifying assumptions that are implicit in the formulae and the model as a whole.**

Now, copy the second row down until you reach row 200. Play with the initial airspeed and vary your load factor throughout the turn to fly the fastest 180-degree turn that you can.

5. **From the lecture, which turn (level or vertical) did you expect to have the best turn performance? From your data, which turn actually worked better? Compare turn rate and average turn radius for each type of turn: horizontal and vertical.**

Finally, I will again award **<u>25 bonus points</u>** to any lab group who can fly their F-4 through a vertical **180 degree** turn in equal or better time than my best effort. I will also award **<u>another additional 25 bonus points</u>** to the lab group in each section who can make the turn in the shortest time of all your peers. Leave the P_s formulae alone, but you may change ***initial*** airspeed, initial direction of pull, initial angle, and the load factor throughout the turn. **For part two of the exercise, turn in only the graph "Angle turned vs. time", clearly labeled as being your data for the *vertical* turn, and annotated with your best half-circle time.**